OCR
RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced Subsidiary GCE

Unit **F322:** Chains, Energy and Resources

Mark Scheme for January 2013

Oxford Cambridge and RSA Examinations

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Annotations

Annotations available in Scoris.

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Generic comments

ORGANIC STRUCTURES

For a 'structure' or 'structural formula',

- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,

- **ALLOW** bond drawn to C or H,
  eg **ALLOW** CH_3–,CH_2–, C_3H_7–, etc
- **ALLOW** vertical 'bond' to any part of an alkyl group

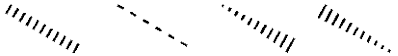
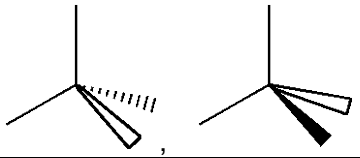
For an OH group shown within a structure,

- **DO NOT ALLOW** formula with horizontal —HO **OR** OH—
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,

- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge eg:	

NAMES

Names including alkyl groups:

- **ALLOW** alkanyl, eg ethanyl (ie **IGNORE** 'an')
- **DO NOT ALLOW** alkol, eg ethol (ie 'an' is essential)

Names of esters:

- Two words are expected, eg ethyl ethanoate
- **ALLOW** one word, eg ethylethanoate

Names with multiple numbers and hyphens:

Use of 'e'

- **ALLOW** superfluous 'e' , eg propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', eg propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:

- **ALLOW** absence of hyphens, eg propane 1,2 diol

Multiple locant numbers must be clearly separated:

- **ALLOW** full stops: eg 1.2 **OR** spaces: 1 2
- **DO NOT ALLOW eg** 12

Locant numbers in formula must be correct

- **DO NOT ALLOW** propan-3-ol

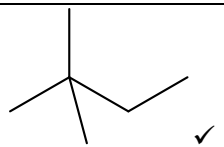
Order of substituents should be alphabetical:

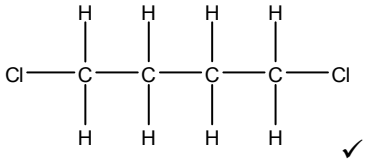
- **ALLOW** any order (as long as unambiguous), eg 2-chloro-3-bromobutane

ABBREVIATIONS

van der Waal's forces

ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

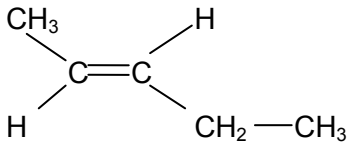
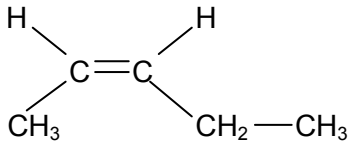
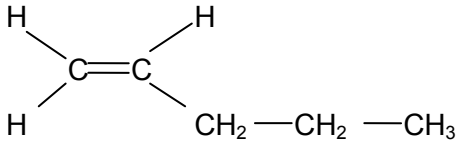
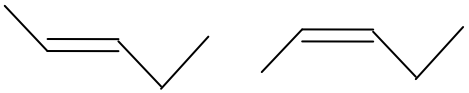
Question			Answer	Marks	Guidance
1	(a)		C_3H_7 ✓	1	**ALLOW** H_7C_3
	(b)		***Saturated*** **Only** has (carbon to carbon) single bonds ✓ ***Hydrocarbon*** Contains (the elements) hydrogen and carbon **only** ✓	2	**ALLOW** does not contain any (carbon to carbon) double bonds **ALLOW** all of the carbon atoms are bonded to four other atoms **DO NOT ALLOW** contains hydrogen and carbon **DO NOT ALLOW** a mixture of carbon and hydrogen only **DO NOT ALLOW** hydrogen and carbon molecules only
	(c)		 ✓	1	
	(d)		as branching increases the boiling point decreases **OR** the more branched the isomers of hexane are the lower the boiling point ✓ branched isomers have less surface (area) of contact **OR** branched fewer points of contact (than unbranched) ✓ (the more branched the) **fewer** van der Waals' forces **OR** (the more branched) has **weaker** van der Waals' forces **OR** Less energy required to break van der Waal's forces ✓	3	**ALLOW** ORA throughout *First marking point must compare boiling point **and** branching for **all** three isomers* Reference to just surface area / closeness of molecules is **not** sufficient **ALLOW** vdw forces **OR** VDW forces (and any combination of upper and lower cases) **DO NOT ALLOW** VDW mark if answer states that these are between atoms or answer implies that these are bonds
	(e)		$C_{10}H_{22} \rightarrow C_6H_{14} + C_4H_8$ **OR** $C_{10}H_{22} \rightarrow C_6H_{14} + 2C_2H_4$ ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** state symbols

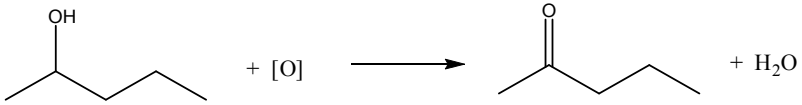
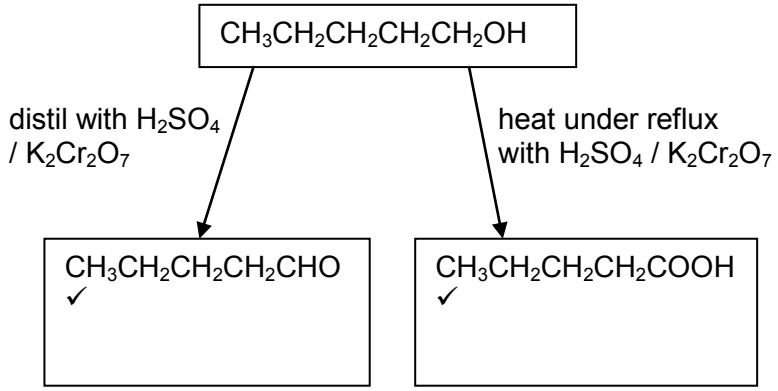
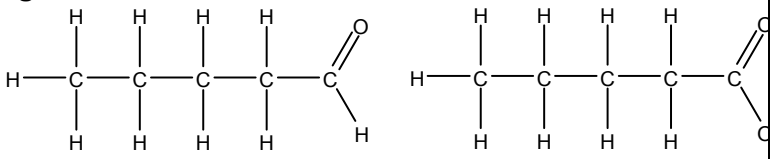
Question			Answer	Marks	Guidance
1	(f)	(i)	$C_4H_{10} + 2Cl_2 \rightarrow C_4H_8Cl_2 + 2HCl$ ✓	1	**IGNORE** state symbols
		(ii)	<table><tr><th>Isomer 1</th><th>Isomer 2</th></tr><tr><td></td><td>1,3-dichlorobutane ✓</td></tr><tr><td>Correct displayed formula eg:  ✓</td><td></td></tr></table>	2	**Must be a displayed formula** **ALLOW** absence of hyphens 1 and 3 must be clearly separated: **ALLOW** full stops: 1.3 **OR** spaces: 1 3 **DO NOT ALLOW** 13
	(g)	(i)	covalent bond breaking ✓ one electron (from the bond pair) goes to each atom **OR** makes (two) radicals ✓	2	**ALLOW** covalent bond is split **IGNORE** particle for atom **DO NOT ALLOW** molecule or compound for atom **DO NOT ALLOW** to each molecule or to each reactant **ALLOW** one electron goes to each product / species **IGNORE** homolytic fission equations
		(ii)	$Cl + C_4H_9Cl \rightarrow C_4H_8Cl + HCl$ ✓ $C_4H_8Cl + Cl_2 \rightarrow C_4H_8Cl_2 + Cl$ ✓	2	**IGNORE** dots even if incorrect
	(h)		$C_4H_{10} + 4½O_2 \rightarrow 4CO + 5H_2O$ **OR** $C_4H_{10} + 2½O_2 \rightarrow 4C + 5H_2O$ ✓	1	**ALLOW** any correct multiples for these equations eg $2C_4H_{10} + 9O_2 \rightarrow 8CO + 10\ H_2O$ **IGNORE** state symbols **ALLOW** equations for incomplete combustion that give CO_2 with CO and/or C eg $C_4H_{10} + 4O_2 \rightarrow 3CO + C + 5H_2O$
			Total	**16**	

Question			Answer	Marks	Guidance
2	(a)		(enthalpy change for the) formation of one mole (of P_4O_{10}) ✓ from (constituent) elements **OR** from P_4/phosphorus and O_2/oxygen ✓	2	**ALLOW** energy required **OR** energy released **ALLOW** makes one mole of product/substance/molecule/ compound **ALLOW** made from P and O_2 **OR** made from two elements **IGNORE** comments related to standard conditions
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –368 (kJ mol^{-1}) award 3 marks** (+)2984 +(+)6 × 286 **OR** (+)2984 +(+)1716 **OR** (+)4700 ✓ (−)1267 × 4 **OR** (–)5068 ✓ −368 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors.** **IGNORE** sign **IGNORE** sign **ALLOW ECF** for enthalpy change of products – enthalpy change of reactants **ALLOW for 2 marks:** +368 cycle wrong way around **OR** −1798 no × 6 **OR** (+)3433 no x 4 **OR** −3352 missing 2984 **OR** (+) 9768 product the wrong sign around **OR** (−) 9768 reactants the wrong sign **ALLOW for 1 mark:** (+)1798 no x 6 and cycle wrong way around **OR** –3433 cycle wrong way around and not × 4 **OR** (+)3352 missing 2984 and cycle wrong way around **OR** (+)2003 no x 6 or x 4 **OR** (+)449 missing 2984 and x 4 **OR** −4782 missing 2984 and x 6 **Note:** There may be other possibilities.

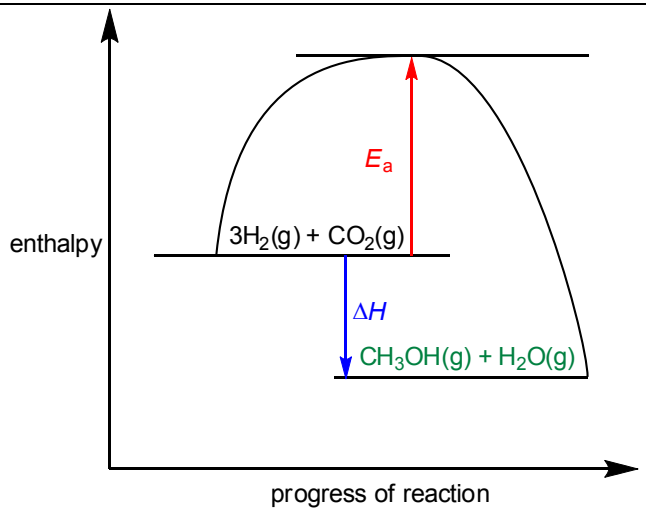
Question			Answer	Marks	Guidance
	(c)		$P_4 + 5O_2 + 6H_2O \rightarrow 4H_3PO_4$ ✓ Only the **desired product** is made ✓ **Second marking point can only be awarded if the equation is correct.**	2	**ALLOW** there are no waste products **OR** there are no by-products **OR** there is only one product. **DO NOT ALLOW** it is an addition reaction
			Total	**7**	

Question			Answer	Marks	Guidance
3	(a)	(i)	acid ✓	1	**ALLOW** named mineral acid or correct formula eg phosphoric acid, H_3PO_4, sulfuric acid, H_2SO_4 or H^+ **DO NOT ALLOW** any carboxylic acids
		(ii)	$C_5H_{12}O \rightarrow C_5H_{10} + H_2O$ ✓	1	**DO NOT ALLOW** use of $C_5H_{11}OH$
		(iii)	***structural isomerism*** have the same molecular formula ✓ but different structural formulae ✓ ***stereoisomerism*** have the same structural formula ✓ but different arrangement (of atoms) in space ✓	4	Same formula is **not** sufficient **ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula Different formula or different arrangement of atoms is **not** sufficient **ALLOW** different **structural** arrangement (of atoms) **ALLOW** have the same structure Stereoisomers have the same formula or molecular formula is **not** sufficient **ALLOW** different spatial arrangements (of atoms)

Question			Answer	Marks	Guidance
3	(a)	(iv)	 **A**  **B**  **C** Correct structure for **A** ✓ Correct structure for **B** ✓ Correct structure for **C** ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **A** and **B** must clearly show cis and trans configuration **eg**  **A** ***B*** **Answers to A and B are interchangeable** **C:** $CH_2CHCH_2CH_2CH_3$ **ALLOW** $-C_2H_5$ group in A or B or $-CH_2C_2H_5$ in C **DO NOT ALLOW** $-C_3H_7$ group in C

Question			Answer	Marks	Guidance
3	(a)	(v)	carbon–carbon double bond ✓ **Each** carbon atom in the double bond is attached to (two) different groups/atoms ✓	2	**IGNORE** comments about rotation **ALLOW** carbon double bond **ALLOW Each** carbon atom of the double bond is attached to a H and an alkyl group **DO NOT ALLOW** functional groups for groups **DO NOT ALLOW** the carbon atoms are attached to different groups "**Each** carbon atom in the double bond" implies a carbon–carbon double bond for the first marking point
	(b)		 Correct **skeletal** structure of product ✓ Balanced equation ✓	2	Balancing mark can only be awarded if the equation has a correct **skeletal** formula for the product
	(c)		 	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **eg**  **ALLOW** CO_2H for the carboxylic acid **DO NOT ALLOW** COH for aldehyde **IGNORE** names
			Total	**15**	

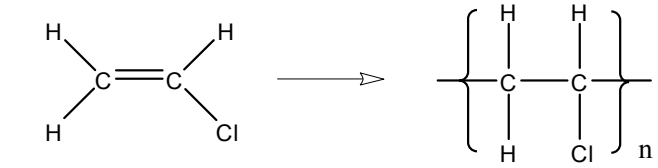
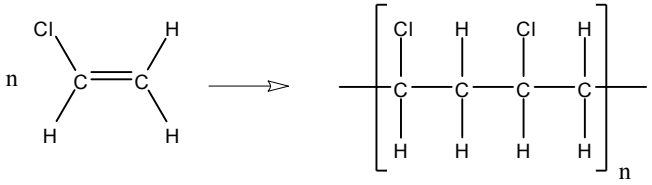
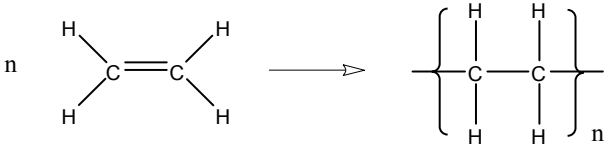
Question			Answer	Marks	Guidance
4	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 681 (kJ) award 3 marks** Evidence of dividing 1000 by 24 Evidence of dividing by 3 and multiplying by 49 in the calculation energy released = 681 (kJ) ✓ **(MUST BE TO 3 SIG FIGS)** --- **Alternative Working** 3 moles = 72 dm^3 ✓ So $\frac{1000}{72}$ or 13.9 ✓ Energy released = 13.9 × 49 = 681 (kJ)	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **ALLOW** 41.7 up to calculator value 41.6666667 correctly rounded. **ALLOW** $\frac{1000}{24}$ for first marking point if not calculated **ALLOW** energy released per mole = 16.3 ✓ **IGNORE (–) sign in the answer** **Common Incorrect answers** **0.392** scores 2 marks **392000** scores 2 marks

Question	Answer	Marks	Guidance
4 (b)		3	
	CH_3OH and H_2O added as product **AND** shown below the reactants ✓		**IGNORE** state symbols for the products
	ΔH labelled with arrow pointing towards products or the product line if no products stated ✓		**IF** there is **no ΔH labelled** then **ALLOW** –49 only as an alternative label for ΔH **IF ΔH is labelled** then **IGNORE** any numerical value **DO NOT ALLOW** $-\Delta H$ **ALLOW** this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line
	E_a labelled correctly **AND** above reactants ✓		**ALLOW** (+) 225 only as an alternative label for E_a **ALLOW** arrows at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve **ALLOW** this line even if it has a small gap at the top and bottom ie does not quite reach the maximum or reactant line **ALLOW** A_E or E_a for activation energy

Question			Answer	Marks	Guidance
	(c)		(+)49 ✓	1	**DO NOT ALLOW** –49
	(d)		(+)274 ✓	1	**DO NOT ALLOW –**274 **ALLOW** answer to **(c)** + 225 as **ECF**
	(e)		(equilibrium position shifts) to the left ✓ (Forward) reaction is exothermic **OR** reaction gives out heat **OR** reverse reaction is endothermic **OR** reverse reaction takes in heat ✓ **The explanation mark is dependent on the correct shift of the equilibrium**	2	**ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **Note: ALLOW** suitable alternatives for 'to left', eg: towards CO_2 / H_2 **OR** towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of CH_3OH /products **IGNORE** responses in terms of rate
	(f)		(equilibrium position) shifts to the left ✓ Right-hand side has fewer (gaseous) moles/molecules ✓ **ORA** **The explanation mark is dependent on the correct shift of the equilibrium**	2	**ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **Note: ALLOW** suitable alternatives for 'to left', eg: towards CO_2 / H_2 **OR** towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of CH_3OH /products **IGNORE** responses in terms of rate **ALLOW** four moles on the left and two moles on the right **ALLOW** more moles of reactants or fewer moles of products **ASSUME** "goes the side with more gas molecules" implies from equation that more molecules on the left **OR** "goes to side with fewer gas molecules" implies from equation that fewer molecules are on the right

Question			Answer	Marks	Guidance
	(g)		Adsorption of reactants **OR** adsorption of gases **OR** H_2 and CO_2 attached to surface ✓	3	**ALLOW** CO_2 and H_2 (weakly) bonded to surface **OR** reactants bond to surface **OR** CO_2 and H_2 form temporary bonds with the catalyst **DO NOT ALLOW** absorption
			Bonds weaken in reactants **OR** chemical reaction **OR** activation energy decreases ✓		**ALLOW** bonds weaken in H_2 **OR** bonds weaken in CO_2 **OR** C=O bonds weaken **OR** bonds break and new bonds made in product **OR** H_2O and CH_3OH made
			Desorption of products **OR** desorption of H_2O and CH_3OH ✓		**ALLOW** products leave the surface/catalyst **OR** H_2O and CH_3OH no longer bonded to surface/catalyst **ALLOW** deadsorption **OR** adsorb from for desorption **ALLOW** diffuse away for desorption
			Total	**15**	

Question			Answer	Marks	Guidance
5	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 90% award 3 marks** amount of dichloroethane = $\frac{19800000}{99.0}$ **OR** 200000 (mol) **OR** 2×10^5 (mol) ✓ amount of chloroethene = $\frac{11250000}{62.5}$ **OR** 180000 (mol) **OR** 1.8×10^5 (mol) ✓ Calculates percentage yield = $\frac{180000}{200000} \times 100$ = 90 % ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. ***ALLOW approach based on mass for 2nd and 3rd marks*** Theoretical mass of chloroethene = 200000 × 62.5 **OR** 12500000 (g) **OR** 1.25×10^7 (g) ✓ Calculates percentage yield = $\frac{11250000}{12500000} \times 100$ = 90 % ✓ --- ***ALLOW approach based on grams rather than tonnes:*** *n*(dichloroethane) = $\frac{19.80}{99.0}$ **OR** 0.2 (mol) ✓ *n*(chloroethane) = $\frac{11.25}{62.5}$ **OR** 0.18 (mol) **OR** theoretical mass chloroethane = 0.2 × 62.5 **OR** 12.5 g ✓ % yield = $\frac{0.18}{0.20} \times 100$ = 90 % **OR** $\frac{11.25}{12.5} \times 100$ = 90 % ✓ --- **ALLOW ECF** throughout from wrong M_r value(s) with final % yield to 2 or more significant figures **DO NOT ALLOW** final mark for an answer above 100% --- **Note**: If this is the only working seen award no marks ie $\frac{11.25 \times 10^6}{19.80 \times 10^6} \times 100$ = 56.81%

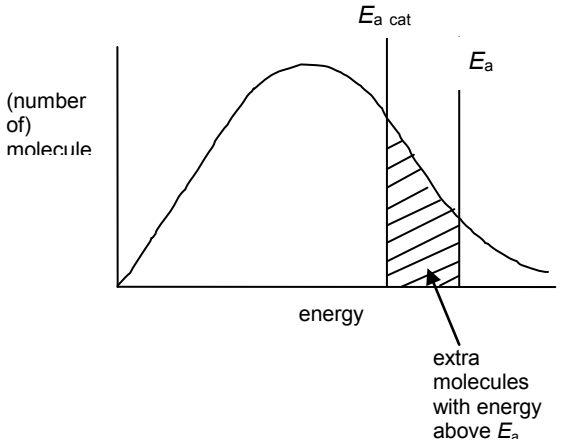
Question			Answer	Marks	Guidance
5	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = (+)62 award 3 marks** ΔH for bonds broken = 2691 (kJ mol^{-1}) ✓ ΔH for bond formed = 2629 (kJ mol^{-1}) ✓ ΔH = (+)62 (kJ mol^{-1}) ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible. **IGNORE** sign **ALLOW** 1106 (C–Cl, C–C and C–H bonds) **IGNORE** sign **ALLOW** 1044 (H–Cl and C=C bonds) **ECF** based on bonds broken – bonds formed **ALLOW** 2 marks for –62
	(c)		Displayed formulae of monomer and polymer required for the marks.  Only chloroethene on left hand side ✓ Only the correct polymer on right hand side ✓ A correctly balanced equation using displayed formulae for any monomer and matching polymer including the correct use of *n* ✓	3	Polymer must have **side** links (do not have to cut through bracket and can be dotted lines) **ALLOW** a correct section of the polymer with side links as below would score two marks as the equation is not balanced  **DO NOT ALLOW ECF** from wrong monomer *n* on LHS can be at any height to the left of formula **AND** *n* on the RHS must be a subscript (essentially below the side link) The equation below would be worth 1 mark for balancing 

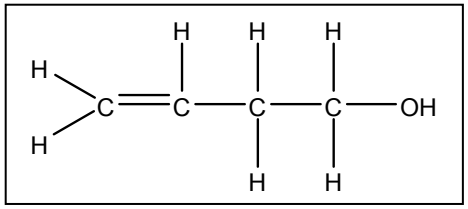
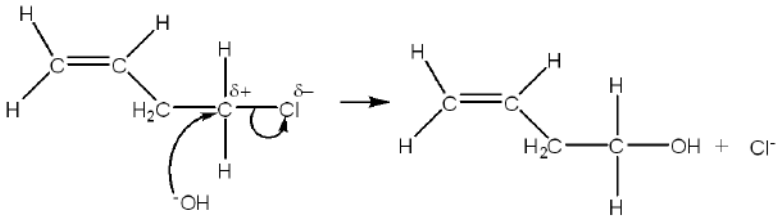
Question			Answer	Marks	Guidance
	(d)	(i)	React with an alkali **OR** react with a base/carbonate **OR** Bubble through water (to make HCl(aq)) **OR** dissolve in water ✓	1	**ALLOW** react with a named alkali or base eg calcium carbonate, calcium hydroxide, magnesium oxide, ammonia **ALLOW** an appropriate chemical formula **IGNORE** use of gas scrubbers
		(ii)	Sort and recycle ✓ Organic feedstock **OR** cracked ✓	2	**ALLOW** separate and recycle or sorting and remoulding **ALLOW** use for the production organic compounds **OR** synthesis gas **ALLOW** the production of plastics or monomers or new polymers
		(iii)	(Bio) degradable (polymers) **OR** compostable (polymers) **OR** soluble (polymers) **OR** photodegradable (polymers) ✓	1	**IGNORE** a named polymer if degradable **DO NOT ALLOW** any addition polymer eg PTFE
			Total	**13**	

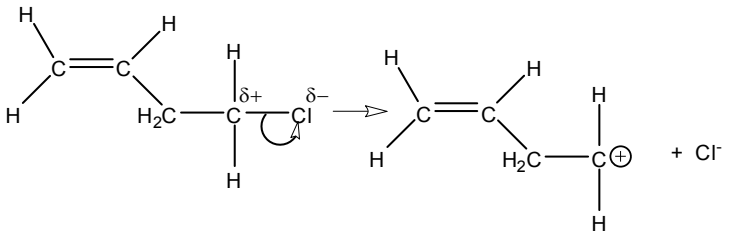
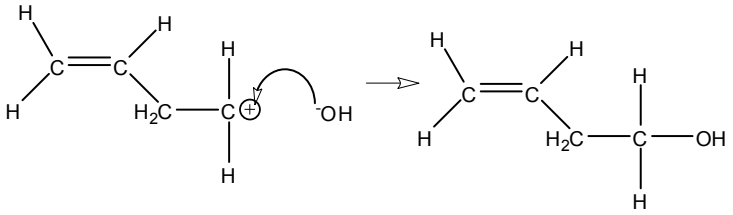
Question			Answer	Marks	Guidance
6	(a)		Bond breaking absorbs energy **AND** bond forming releases energy ✓ More energy released than absorbed ✓ The second marking point is **dependent** on the correct identification of the energy changes during bond breaking and bond making	2	**ALLOW** bond breaking is endothermic **AND** bond forming is exothermic **DO NOT ALLOW** bond forming requires energy **ALLOW** more energy is released when the bond in the products are formed than is required to break the bonds in the reactants **ALLOW** exothermic change transfers more energy than endothermic change **OR** bond forming transfers more energy than bond breaking **OR** '(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants' **OR** '(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken' **OR** more energy associated with bond making than with bond breaking **IGNORE** reference to strong and weak bonds **IGNORE** reference to number of bonds broken or made **IGNORE** enthalpy of products is less than enthalpy of reactants
	(b)	(i)	(C=O) **bond** vibrates (more) **OR bond** bends (more) **OR bond** stretches (more) ✓	1	**IGNORE** molecule vibrates/rotates "It" refers to the molecule and is insufficient **DO NOT ALLOW** any reference to bond breaking. **DO NOT ALLOW** a stated bond if **not** present in CO_2 eg C–O, C–H

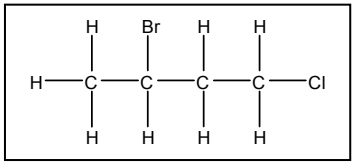
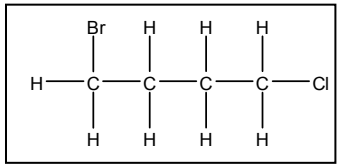
Question			Answer	Marks	Guidance
		(ii)	***Any two from:***	2	**DO NOT ALLOW** reference to carbon being stored – the answer must either refer to carbon dioxide or not mention the name of the stored substance. Assume "it" refers to CO_2
			(injected) **deep** into the oceans / sea ✓		**DO NOT ALLOW** dumping waste at the bottom of the sea **ALLOW on** the **sea-bed** **DO NOT ALLOW** dissolve CO_2 in the sea **OR** (stored) in ocean
			(Stored) in geological formations **OR** (stored) deep in rocks **OR** (stored) in old mines **OR** (stored) in old oil wells **OR** old gas fields ✓		**DO NOT ALLOW** geographical formations **ALLOW** stored **under** the sea (bed) **ALLOW** pumped into oil wells to force last bit of oil out **DO NOT ALLOW** buried underground
			(Stored) by reaction with metal oxides **OR** reaction to form (solid) carbonates **OR** (stored) as a carbonate **OR** equation to show formation of metal carbonate ✓		**DO NOT ALLOW** react with **metals** to form carbonates **IGNORE** mineral storage

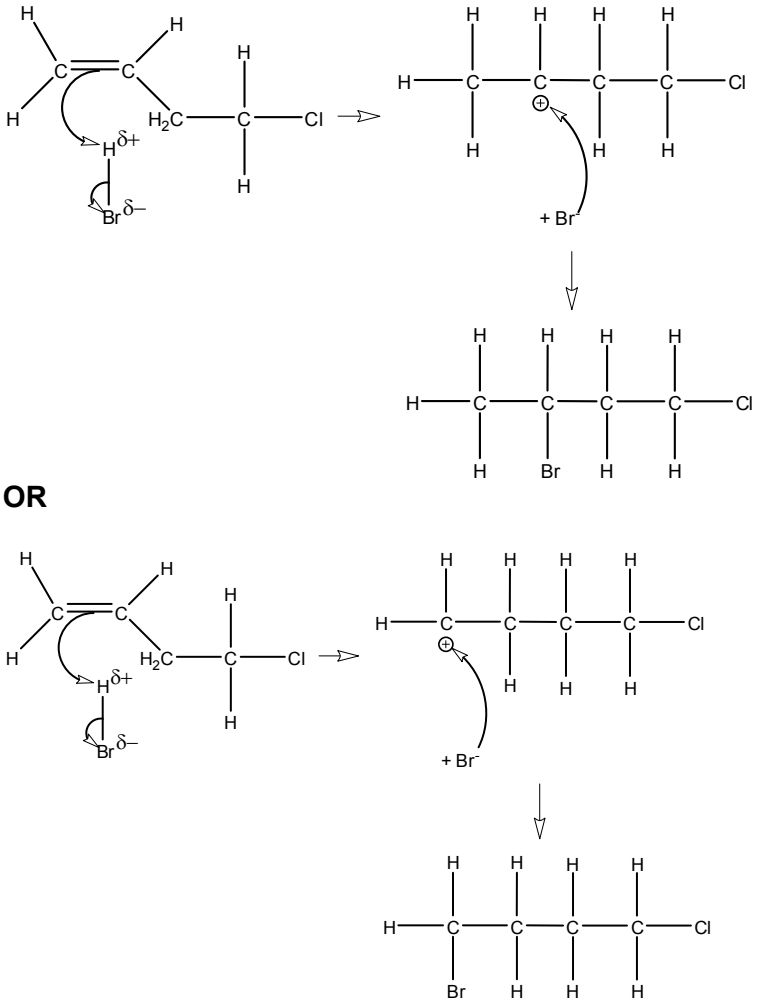
Question	Answer	Marks	Guidance
(c)	***Any two from:***	2	
	Energy demand		
	Low(er) temperature (can be used) **OR** reduces CO_2 emissions (from burning fossil fuels) ✓		**ALLOW** 'allows use of room temperature' **OR** 'allows use of a lower pressure' **OR** uses less fuel **IGNORE** lower energy demand **OR** lower activation energy **IGNORE** cheaper **IGNORE** less greenhouse gases **OR** reduces global warming
	Specificity		
	enzymes have a great deal of specificity ✓		**ALLOW** making specific isomers / enantiomers **ALLOW** for making pure products **ALLOW** generating specified products
	Atom economy		
	greater atom economy **OR** less waste ✓		**ALLOW** increases atom economy
	Toxicity		
	can reduce use of toxic solvents **OR** reduces use of toxic catalysts **OR** reduces the use of toxic reactants ✓		**ALLOW** reduce use of hazardous/toxic/harmful/poisonous chemicals **ALLOW** enzymes are non toxic **IGNORE** can be reused

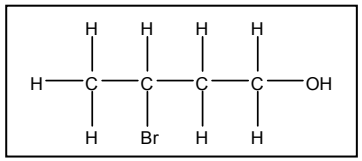
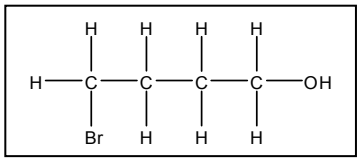
Question	Answer	Marks	Guidance
(d)	Catalyst lowers the activation energy (because of a different reaction pathway) ✓	5	Can be scored from the diagram by correctly labelling $E_{a\ cat}$ closer to the origin than E_a
	Diagram of Boltzmann distribution ✓		Boltzmann distribution must start at origin **AND** must not touch *x*-axis at high energy
	axes labelled (number of) molecules and energy ✓		**DO NOT ALLOW** Boltzmann distribution mark if **two** curves drawn
			**DO NOT ALLOW Boltzmann distribution** curve bending upwards at higher energy **ALLOW** particles instead of molecules **DO NOT ALLOW** the first use of atoms but credit atoms if used in a subsequent marking point **DO NOT ALLOW** enthalpy on x-axis instead of energy
	Greater proportion of molecules with energy above activation energy with catalyst ✓		**ALLOW** more molecules with energy above activation energy (with a catalyst) **OR** more molecules overcome the activation energy (with a catalyst) **OR** more molecules have enough energy to react (with a catalyst) **OR** more molecules are able to react at lower energies
	more **effective** collisions **OR** more **successful** collisions **OR** increased frequency of **successful** collisions ✓		More collisions **OR** more frequent collisions are **not** sufficient
	Total	**12**	

Question			Answer	Marks	Guidance
7			**Nucleophilic substitution reaction** **correct equation for the reaction** ✓ $CH_2CHCH_2CH_2Cl$ + KOH → $CH_2CHCH_2CH_2OH$ + KCl **OR** C_4H_7Cl + KOH → C_4H_7OH + KCl **correct product of the reaction** ✓  **Mechanism**  dipole shown on C—Cl bond: $C^{\delta+}$ and $Cl^{\delta-}$ in the correct chloroalkene ✓ curly arrow from HO^- to carbon atom of C–Cl bond **AND** curly arrow from C–Cl bond to chlorine atom ✓ formation of Cl^- ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** $CH_2CHCH_2CH_2Cl + OH^- \rightarrow CH_2CHCH_2CH_2OH + Cl^-$ **ALLOW** $C_4H_7Cl + OH^- \rightarrow C_4H_7OH + Cl^-$ **ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **For structure of the product** **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) if seen **ONCE** in equation, mechanism or drawn out eg $CH_2CHCH_2CH_2OH$ curly arrow must start from one lone pair on O atom of ^-OH ion **OR** from negative charge on the O atom of the ^-OH ion Lone pair does **not** need to be shown on ^-OH ion

Question	Answer	Marks	Guidance
	Nucleophilic substitution continued (S_N1) **Step 1:**  **Step 2:** 		**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW S_N1 mechanism** dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ in correct chloroalkene ✓ curly arrow from C–Cl bond to halogen atom and Cl^- ✓ curly arrow from ^-OH to **correct** carbocation ✓ curly arrow must start from one lone pair on O atom of ^-OH ion **OR** from negative charge on the O atom of the ^-OH ion Lone pair does **not** need to be shown on ^-OH ion

Question			Answer	Marks	Guidance
7			**Electrophilic addition** **correct equation for the reaction** ✓ $CH_2CHCH_2CH_2Cl + HBr \longrightarrow CH_3CHBrCH_2CH_2Cl$ **OR** $CH_2CHCH_2CH_2Cl + HBr \longrightarrow CH_2BrCH_2CH_2CH_2Cl$ Indication that there are two possible addition products ✓ **Correct product** ✓  **OR**  **Mechanism** Curly arrow from C=C of correct chloroalkene to attack the H atom in HBr ✓ Correct dipole on H–Br: $H^{\delta+}$ and $Br^{\delta-}$ **AND** curly arrow from H–Br bond to Br ✓ Correct carbocation / carbonium ion with the **full** positive charge shown: C^+ **AND** correct curly arrow from lone pair of Br^- to correct carbon atom **OR** correct curly arrow from negative charge of Br^- to correct carbon atom ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above. **eg** $C_4H_7Cl + HBr \rightarrow C_4H_8BrCl$ For the structure of the product **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) if seen **ONCE** in equation, mechanism or drawn out eg $CH_2BrCH_2CH_2CH_2Cl$ or $CH_3CHBrCH_2CH_2Cl$ curly arrow must start from covalent bonds and not atoms Lone pair does **not** need to be shown on ion or used in mechanism **DO NOT ALLOW** any other partial charges eg shown on double bond **DO NOT ALLOW** $C^{\delta+}$ for charge on carbonium ion. Curly arrow from Br^- can start from the negative charge or the lone pair **DO NOT ALLOW** delta negative, i.e. $Br^{\delta-}$

Question			Answer	Marks	Guidance
7			**Electrophilic addition continued**  **OR** 		
			heterolytic fission for **both** mechanisms and **not** contradicted ✓	1	

Question			Answer	Marks	Guidance
			ALTERNATIVE APPROACH **The Candidate who reacts with KOH followed by HBr** • Award all marks for the nucleophilic substitution mechanism as per the marking scheme • You can award all marks for the electrophilic addition mechanism; however the product will be one of the following:  **OR**  • The mechanism will be the same except the –C*l* will now be replaced by –OH at every stage		
			Total	**12**	

Question			Answer	Marks	Guidance
8			**IR spectrum** (absorbance between) 3200–3550 cm^{-1} indicates –OH **AND** X is an alcohol ✓	1	**LOOK ON THE SPECTRUM** for labelled absorbance which can be given credit **ALLOW** an absorbance within the range 3100 to 3700cm^{-1} from the spectrum. Answer must give –OH and alcohol for the mark. **IGNORE** phenol **DO NOT ALLOW** carboxylic acid (there is no carbonyl group present in the spectrum)
			Formula **mole ratio C : H : O** $\frac{0.600}{12} : \frac{0.133}{1.0} : \frac{0.267}{16}$ **OR** 0.0500 :0.133 : 0.0167 ✓ $\frac{0.05}{0.0167} : \frac{0.133}{0.0167} : \frac{0.0167}{0.0167}$ **OR** 3 : 8 : 1 **OR** C_3H_8O ✓ Candidate links $\mathbf{C_3H_8O}$ to 60 such as $\mathbf{C_3H_8O}$ has M_r 60 **OR** $\mathbf{C_3H_8O}$ has m/z = 60 ✓	3	Must be a clear link between the **formula** and the M_r **OR** m/z **ALLOW** evidence of M_r , eg (12 x 3) + (8 x 1) + 16; 36 + 8 + 16 = 60 **ALLOW** alternative approach for empirical formula and evidence that 60 is equal to C_3H_8O M_r = 60 Carbon: $60 \times \frac{60}{100} = 36$ Hydrogen: $60 \times \frac{13.3}{100} = 8$ 36/12 = 3 C 8/1 = 8H 36 + 8 = 44 60 – 44 = 16 so 1 O C_3H_8O

Question			Answer	Marks	Guidance
8			**Identification and equation**	6	
			X is $CH_3CH_2CH_2OH$ **OR** $CH_3CHOHCH_3$ **OR** either $CH_3CH_2CH_2OH$ or $CH_3CHOHCH_3$ ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** names
			QWC Stated in words that **Y** must be an ester because it is made from the reaction of a **carboxylic acid** **AND X (propan-1-ol OR propan-2-ol OR** an **alcohol**) ✓		**ALLOW** a carboxylic acid reacts with an alcohol to give an ester. **IGNORE** ethanoic acid (as this is stated in the question)
			Y is $CH_3COOCH_2CH_2CH_3$ **OR** $CH_3COOCH(CH_3)_2$ **OR** either $CH_3COOCH_2CH_2CH_3$ or $CH_3COOCH(CH_3)_2$ ✓ Must be consistent with a structure of alcohol **X**		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) If no structure of **X** is provided one mark can be awarded for a correct structure of $CH_3COOCH_2CH_2CH_3$ **OR** $CH_3COOCH(CH_3)_2$
			m/z = 31 is CH_2OH^+ ✓		**DO NOT ALLOW** CH_3O^+
			QWC m/z = 31 or CH_2OH indicates that X must be $CH_3CH_2CH_2OH$ **OR** cannot be $CH_3CH(OH)CH_3$ **OR** shows that X is the primary alcohol ✓		**QWC** must link the evidence to the structure of propan-1-ol.
			$C_3H_8O + C_2H_4O_2 \rightarrow C_5H_{10}O_2 + H_2O$ ✓		In equation **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	**10**	

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